

THERMOSTATIC TEMPERATURE CONTROL
FOR GAS ENGINE JACKET WATER

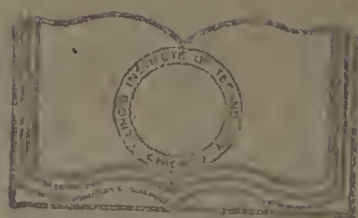
BY

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ARMOUR INSTITUTE OF TECHNOLOGY


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THERMOSTATIC TEMPERATURE CONTROL FOR GAS ENGINE JACKET WATER

A THESIS

PRESENTED BY

MORTON G. GROSS AND ALBERT J. STEINER

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE


IN

MECHANICAL ENGINEERING

JUNE 2, 1921

APPROVED

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Thermostatic Jacket Water Control of A Gas Engine.

Object.

During the course of years of gas engine engine testing at the Armour Institute of Technology, need was found for some device to automatically, control the jacket water temperature of the engine, under test. Heretofore, the temperature was manually controlled, by varying the amount of cold water supplied to the engine. By installing thermostatic control of the water, one of the manual adjustments was done away with, which meant that more time could be given to the many other adjustments and readings that were necessary. A variation of ten degrees in the jacket, meant a considerable percent of error, and by the use of such a device, it was hoped to materially reduce the same.

Conditions.

The valve being for laboratory use, a new design became necessary due to the varying and exact requirements needed in engine testing. The conditions for which the valve was to be designed, were as follows:

1. Close temperature regulation.
2. Thermo - syphon system.
3. City water pressure through a three-eighths inch pipe.
4. A volatile liquid in a Sylphon bulb, for the actuating force on the valve.
5. Brass through - out to resist corrosion.
6. To operate at 150° F. and yet be adjustable as to temperature regulations.
7. To operate at any desired load on the engine.

Bibliography.

The following magazine articles were obtained from the various Engineering indices, as far back as 1913. All writings that in any way pertained to Thermostatic Temperature Control, were recorded and are as follows:

1. Thermostat controls radiator shutter.
Automobile 38:637-9 3-28-18.
2. Thermostatic control considerations.
Automotive Industries 37:292 8-16-17.
3. Thermostatic generator control.
how it proved a success.
Automotive Industries 39:460 9-12-18.
4. Automatic temperature controllers.
Electrical World 71:39-40 7-7-17.
5. Notes on high temperature thermostats.
Engineer 112-322-3 10-12-17.
Engineering 104-412-14 "-19-17.
6. Impulse thermostat for abnormal changes
in temperature.
Engineering and Mining Journal
97-876 4-25-14.
7. Constant temperature water circulated
by a motor driven pump.
Engineering News Record
79:86 7-12-17.

Bibliography. (Continued).

8. Inexpensive thermostat and gas regulator.
Engineering News Record
79:86 1-25-13.
9. Temperature governors.
Gas Age. 38:302-4 8-15-16.
10. Thermostatic Metal. Developed by the
General Electric, to control by heat
or cold.
International Marine Engineering.
23:17-18 1-18.
11. Temperature indicatind and controllong
systems.
Machinery 25:1015-23 7-19.
25:1138-45 8-19.
12. Temperature control for industrial
purposes.
Metallurgical and Chemical Engineering.
12:660-1 10-14.
13. Thermostat
Metallurgical and Chemical Engineering.
17:192-3 8-15-17.

Improved Sarco temperature control regulator,

in Power of Aug. 15, 1916 does not quite

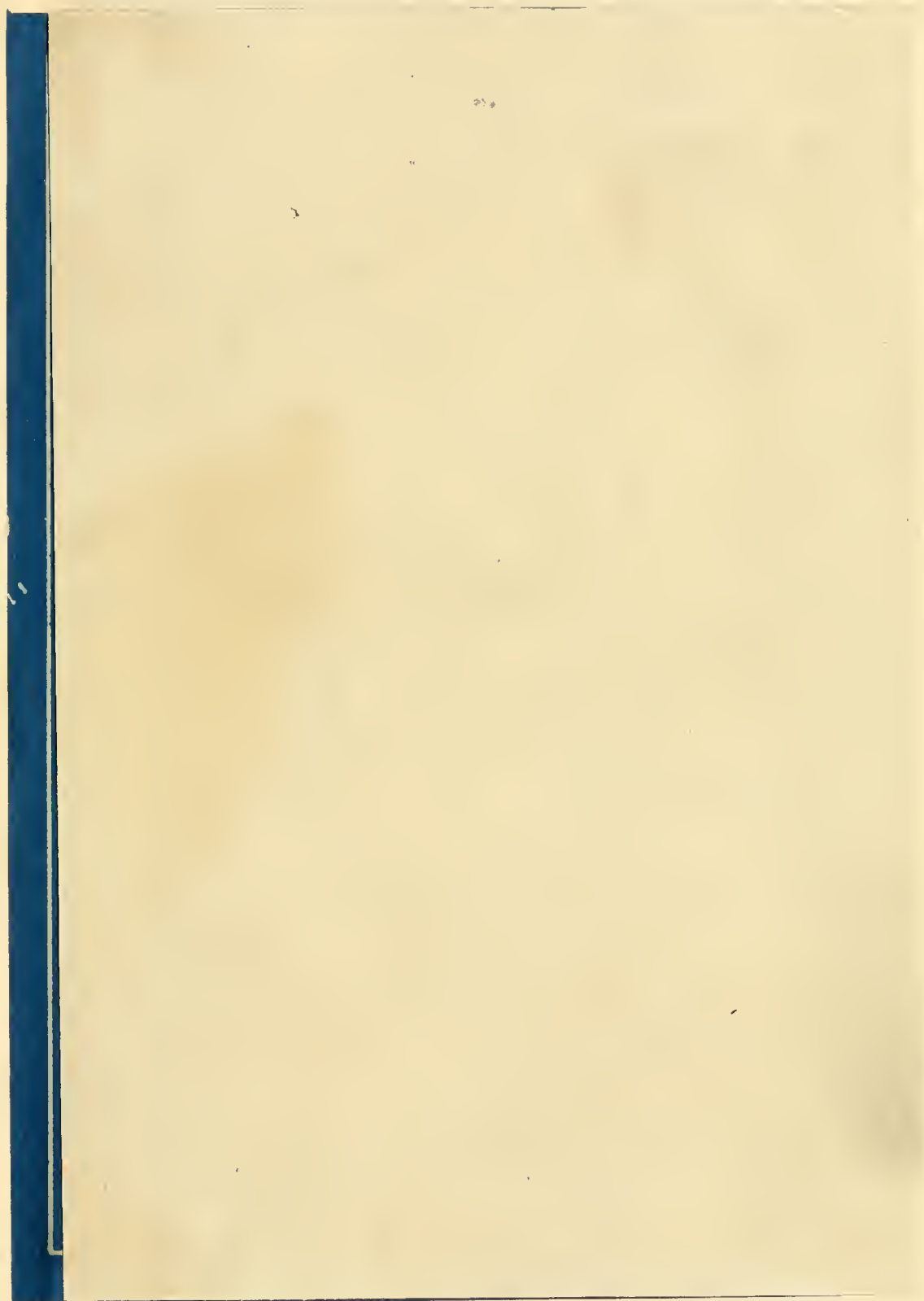
deal with the subject.

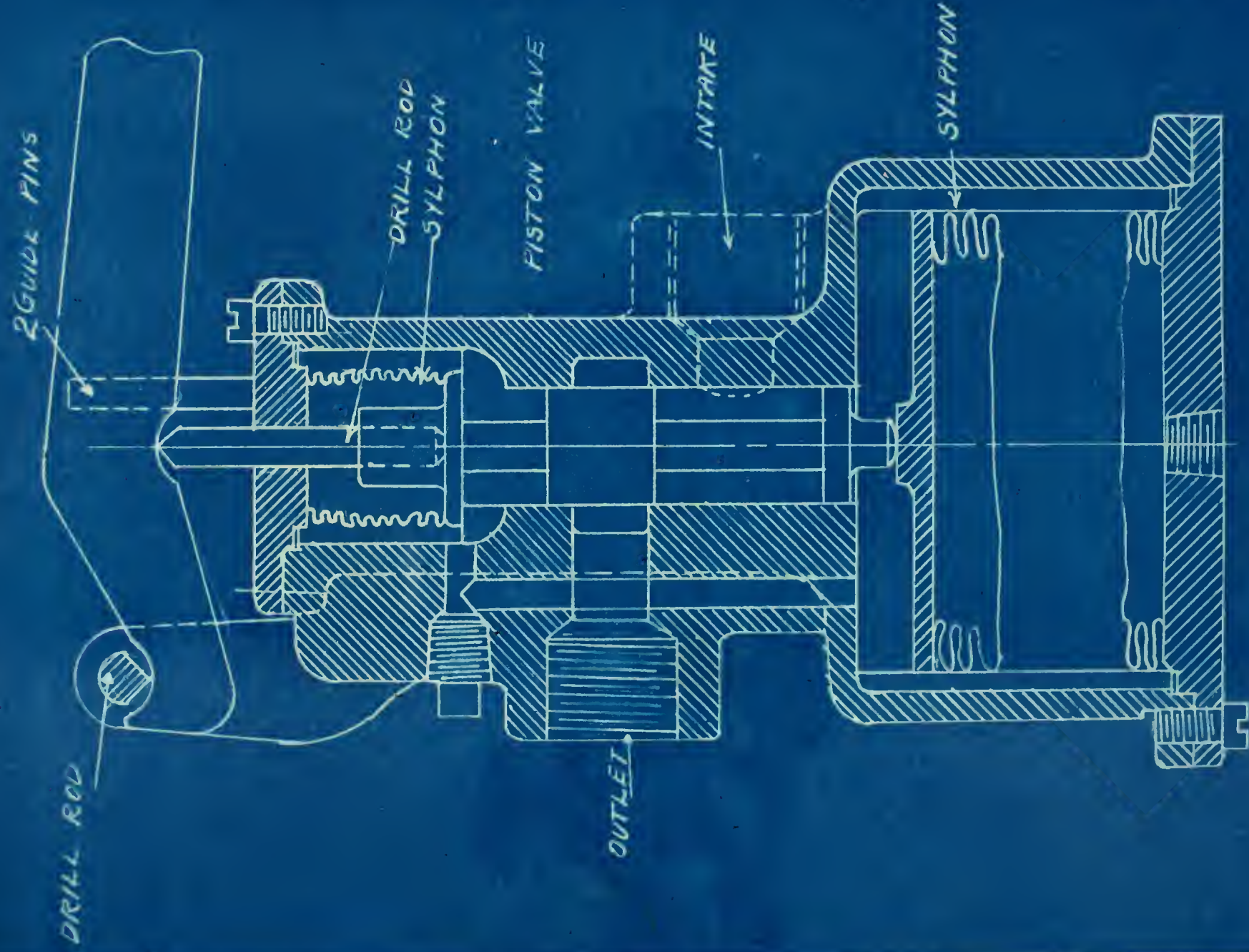
First Considerations.

Having read all the available material on the subject, we decided that it did not fit our conditions, which is a very special case. Most of the data and material found, was for a thermostatic valve to be used on an automobile, where the conditions differed from ours. The pressure in the cooling system of an automobile, is in most cases very small, while we have city water pressure of approximately twenty pounds per square inch. Therefore our aim was to design a valve, that in an ideal case, would be perfectly balanced and yet rugged and simple.

Proposed Design.

A design proposed by the Stewart Warner Corporation, of the piston valve type, shown in drawing, was obtained and looked into.

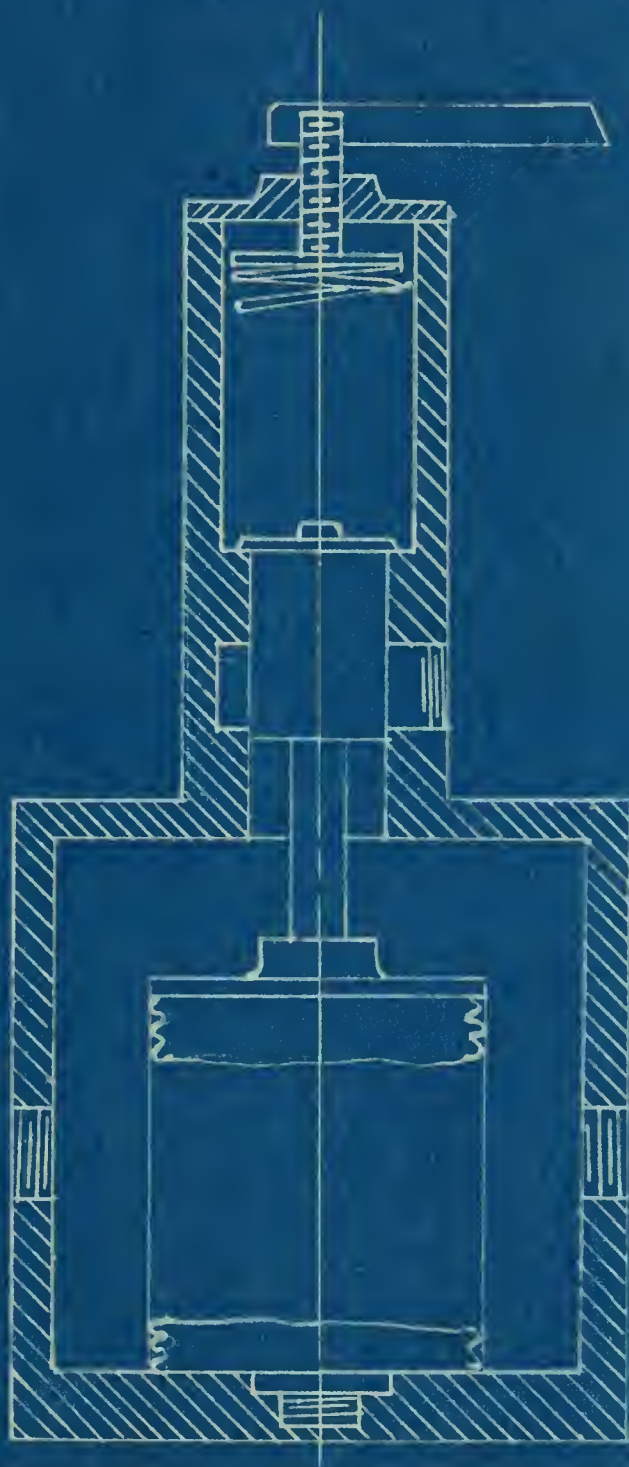




THERMOSTATIC CONTROL
PROPOSED BY
STEWART-WARNER CORP.

PRELIMINARY SKETCH

#1



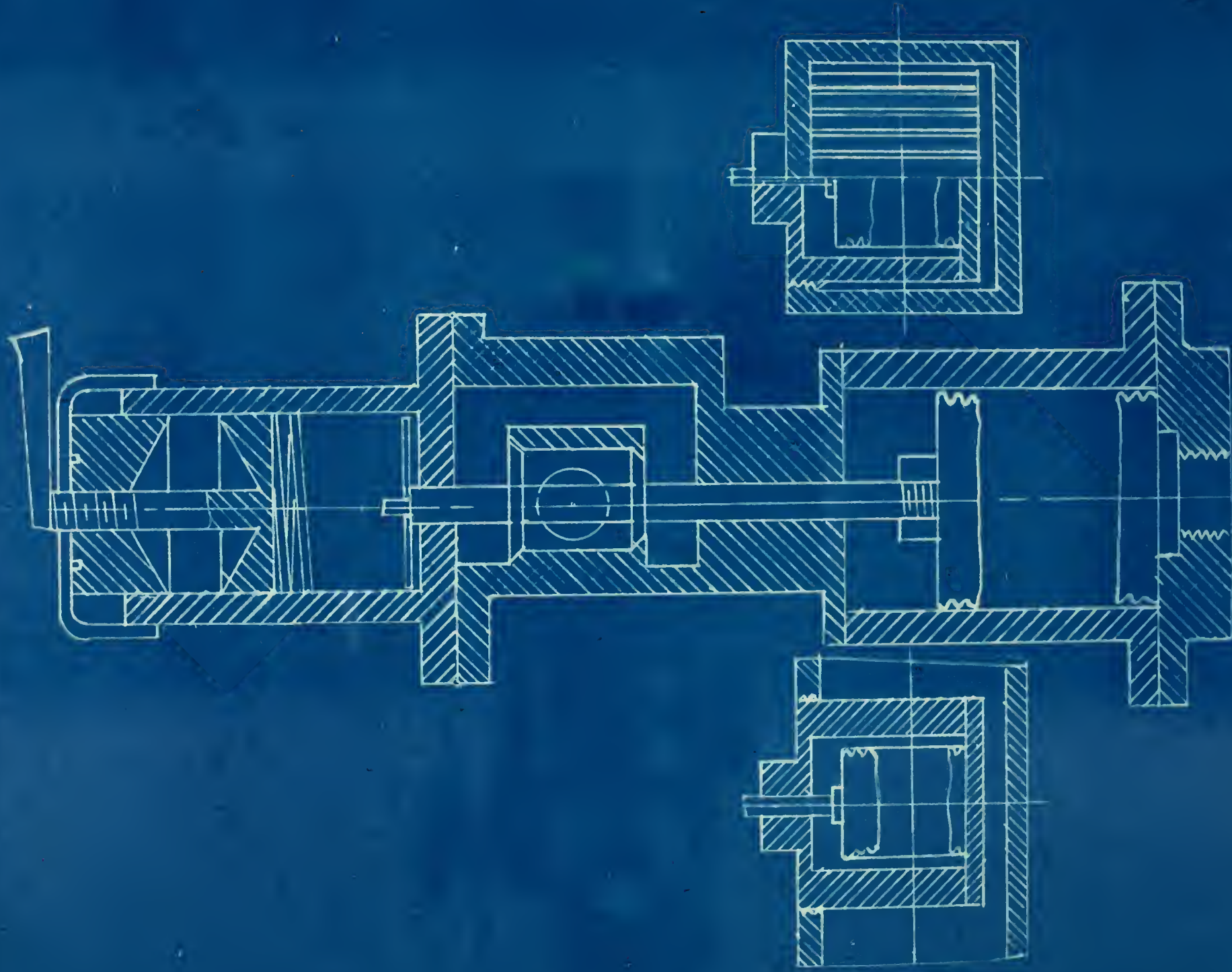


It was found bulky and required accurate machining due to the piston valve. Wear, which would certainly take place, was not provided for and it surely would occur with this type of valve. Although the piston valve has the advantage of being perfectly balanced, leakage would be bound to occur after use. This was the main reason why Preliminary Sketch # 1. was also, discarded. Piston rings would have probably checked the leakage; this meant that additional friction, must be overcome. Allowing that the difficulty of leakage around the valve had been removed, the loss due to friction would far overbalance the gain produced by having a perfectly balanced piston valve.

A balanced poppet valve was then sketched as is shown in Preliminary Sketch # 2., and discussed. Since the first requirement was sensitiveness to effect close regulation, we believed that a balanced valve would be necessary. This type approached the conditions

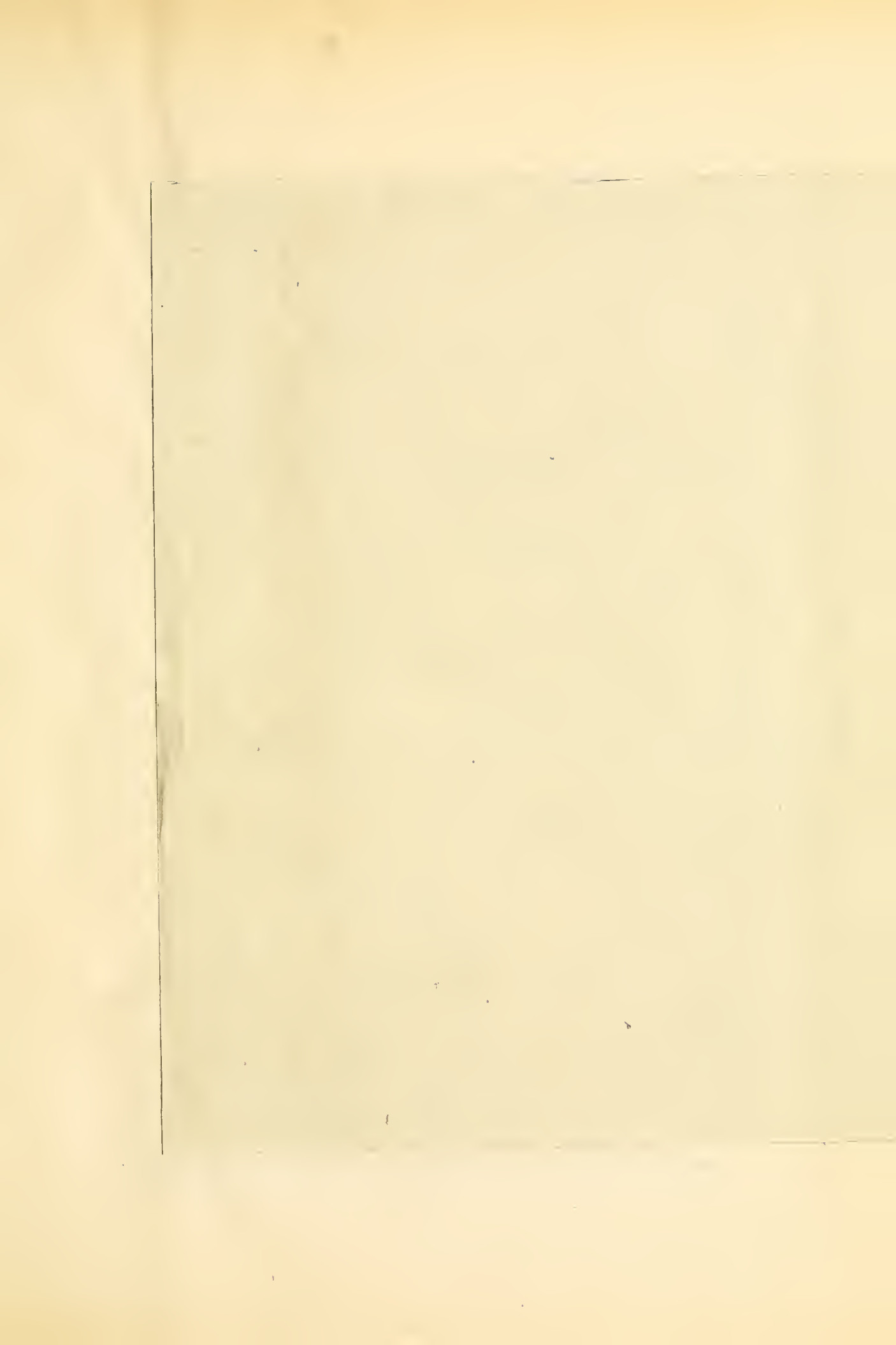
PRELIMINARY SKETCH. "2."

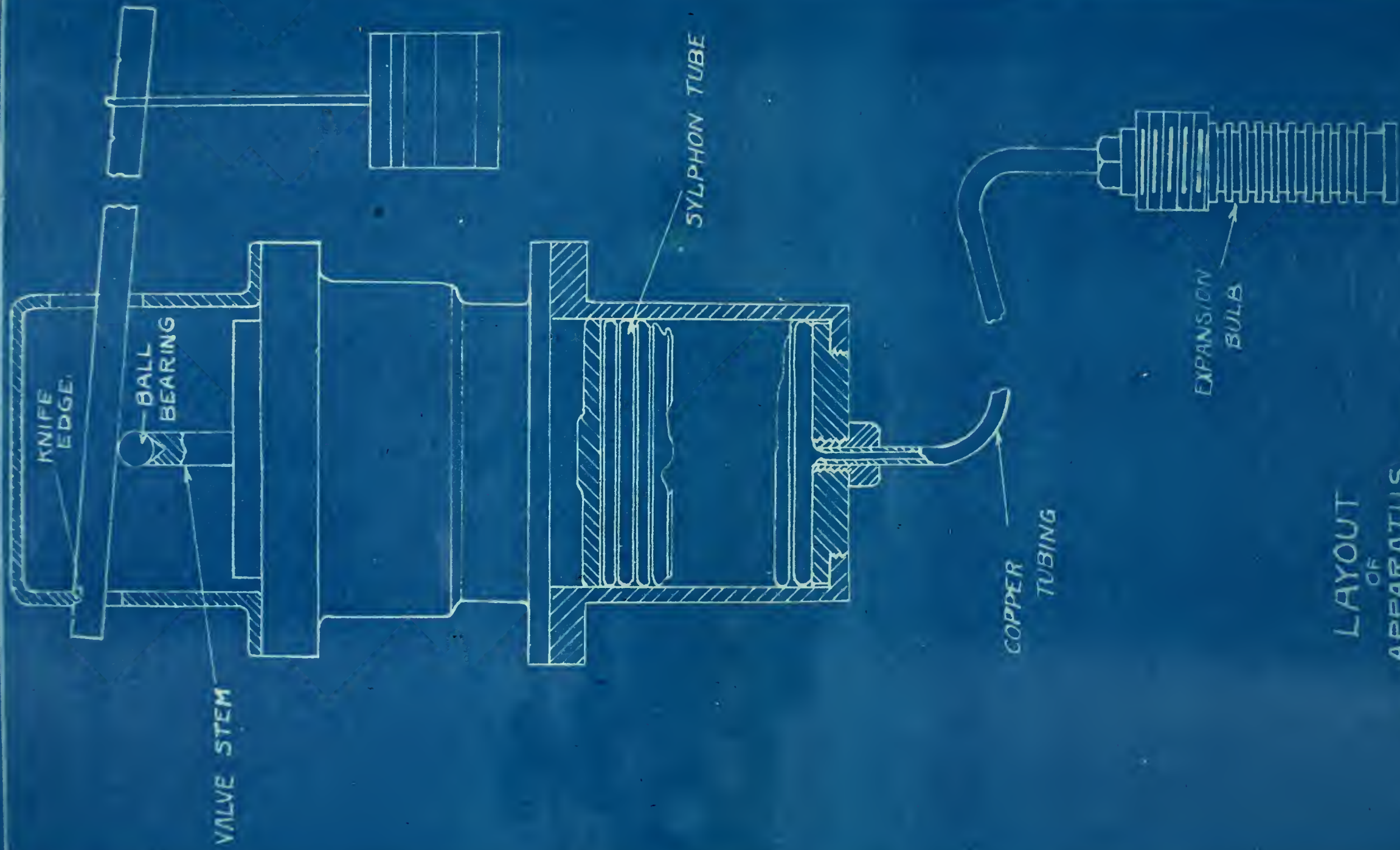
PRELIMINARY SKETCH. '2.



which we desired, and as in an automobile, it could be reground when wear made it necessary. We decided that this was the valve most suitable for our problem.

Details were next developed. At first, remote control was agreed upon and planned for. A small bulb with fins, for better conduction, was designed as shown in the drawing, Layout Of Apparatus During Run of Test, to hold the expanding liquid, which was connected to the Sylphon Bulb by a flexible copper tube. This method was thought desirable, as the valve could be in any convenient place and the bulb inserted in any part of the cooling system. It was plainly evident that some means must be taken, for making the valve body water - tight. Upon first thought it seemed reasonable to put a small stuffing box on the valve stem bearing, but this meant additional friction to overcome, so the stuffing box idea was discarded.





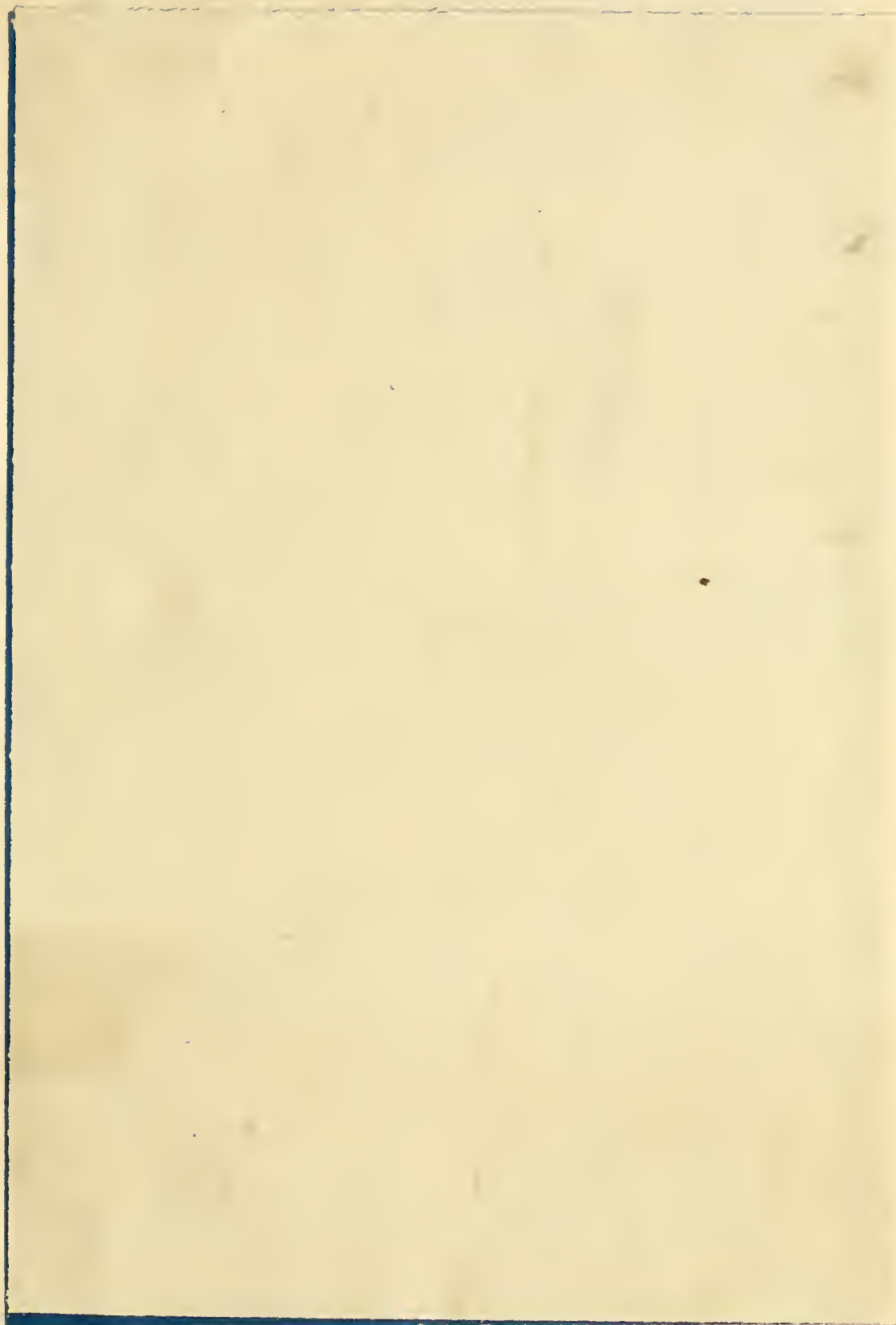
LAYOUT
OF
APPARATUS
DURING RUN OF TESTS.

The leak around the valve was taken care of, by surrounding the stem with a water tight cap. The regulating screw that extends thru the cap, was cut with very fine threads and this effectively reduced the leakage around it.

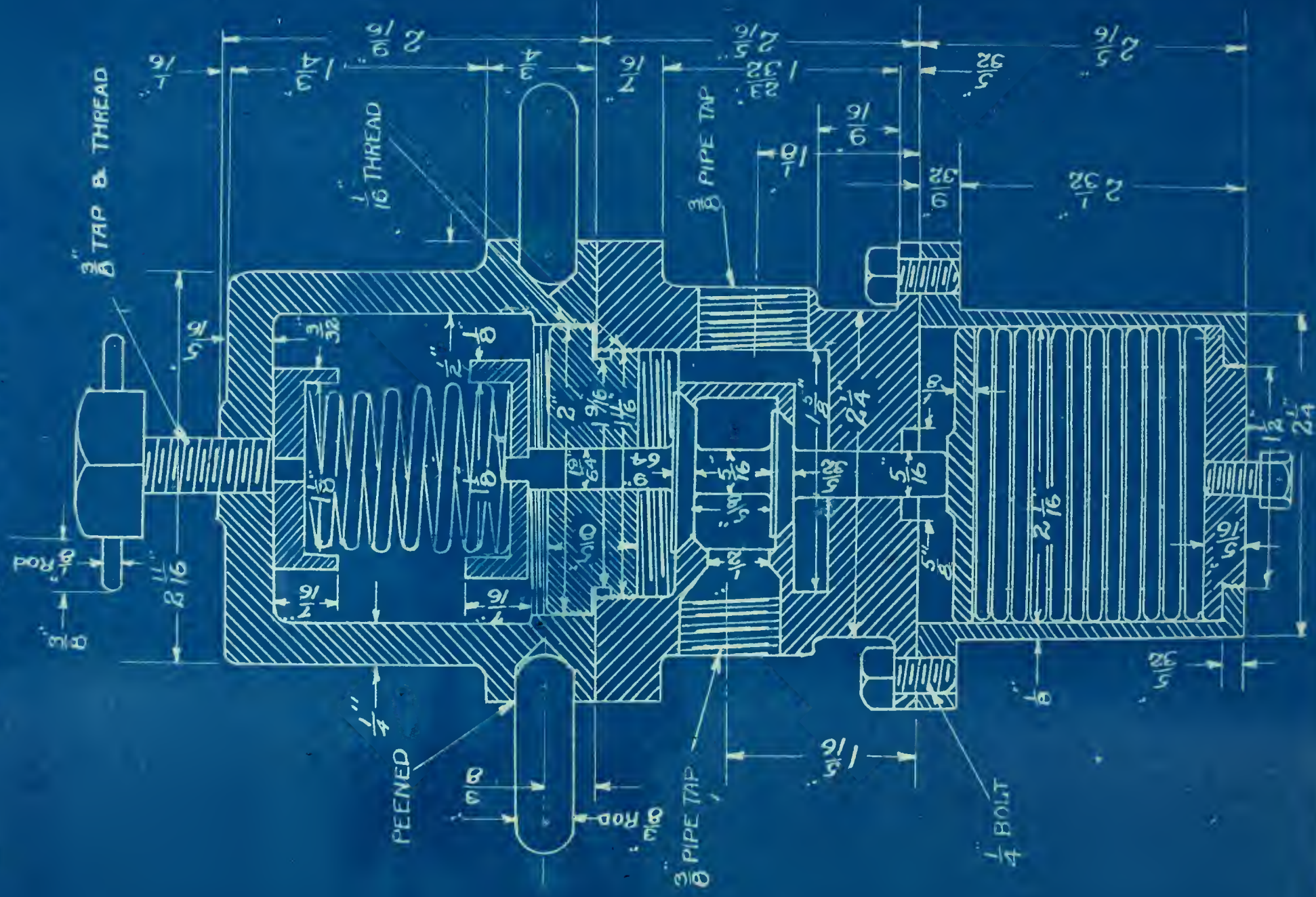
A weighted lever for holding the valve on it's seat, meant a large and clumsy affair, but was used for testing purposes, as it was easy to calculate the amount of pressure on the valve from the moment arms, but for a permanent device accurate spring regulation was used. This is clearly shown in the photographs and drawings. With these ideas in mind, Drawing # 1. was completed.

Operation and Explanation of Valve Assembly (As shown in Drawing # 1.)

A volatile liquid, which is to be found by experiment, that will give a considerable pressure at 150°F. is placed in the Sylphon



SECTION OF





SECTION MIDWAY
BETWEEN VALVE
AND SEATS.

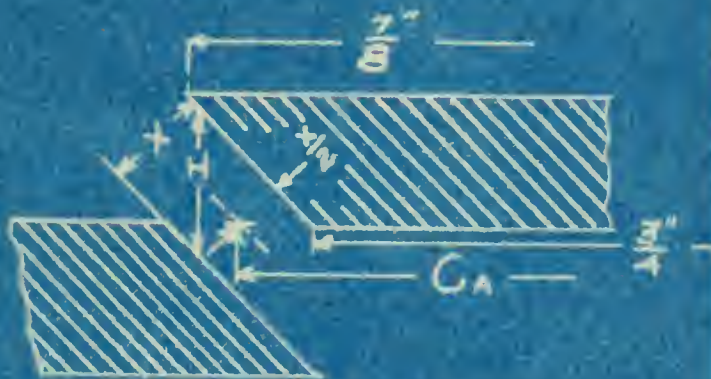
Bulb, and it in turn screwed into it's retainer; the Sylphon tops having been previously soldered in place. The expansion bulb having been fitted with it's copper tube, is then connected to the Sylphon. A paper gasket is placed between the retainer and the valve body, and the two securely fastened together by means of six bolts. The valve stem is made just short enough, so that when the valve seats, the Sylphon Bulb will not be compressed beyond its safe limit. The valve body and the cap are connected, by means of the joining screw and a rubber gasket placed between them, the spring and it's cups having been placed in position. The inlet and outlet pipes are connected into the cooling system, with the city pressure on the inside of the valve chamber. By doing this we reduce the possibility of leakage, as the pressure is only on the joints when the valve lifts.

The action is as follows: As the jacket water heats up, the heat is transmitted to the expansion bulb, vaporizing part of the liquid

and in so doing, produces a pressure that is transmitted to the sylphon bulb by means of the liquid in the flexible copper tube. As the temperature rises the pressure increases, until it overcomes that of the spring or lever as the case may be. The difference in pressure between the liquid and the lever or spring, raises the valve and allows cold water to flow into the cooling system. This reduces the temperature of the jacket water. As the cooled water strikes the expansion bulb, part of the volatile vapor condenses, reducing the pressure below that of the spring and causes the cold water supply to be cut off. In this way, the valve automatically keeps the jacket water at a constant temperature.

The valve being slightly unbalanced
(Shown in the drawings and calculations.)
a little more pressure will be needed to open the valve, than that required to close it, depending upon which side the city pressure happens to be.

SKETCHES FOR CALCULATIONS.



VALVE SECTION





If the city water pressure is in the valve chamber, the unbalanced pressure is less than if the pressure is on the outside. This of course tends to make the valve less sensitive, but indications later in the work show that it has but little effect on the temperature regulation of the valve, but this can be counterbalanced by the load on the valve.

Calculations of The Valve.

Given:

City Pressure = 20 lbs. / Sq. / Inch.

Pipe to be used 3/8 Inch.

Let:

A = Area of the orifice of the
inlet pipe.

X = Perpendicular distance between
the valve and it's seat.

H = Lift of the valve.

At = Area of the opening of the
top valve.

A_b = Area of the opening of the
bottom valve.

C_t = Mean circumference of the top
valve.

C_b = Mean circumference of the
bottom valve.

Therefore:

$$A = .785 \times .54^2 = .23 \text{ Sq. Inch.}$$

Therefore since the area of the pipe opening
is . 23 Sq. Inch , we must make the valve lift,
such that it will give this same size opening.
(See Sketch on Calculations).

Also:

$$\begin{aligned} C_t &= .75 + .5X / \sin 45^\circ \\ &= .75 + .708X \end{aligned}$$

$$A_t = .75X + .708 X^2$$

$$A_b = .625X + .708X^2$$

$$H = X / \sin 45^\circ$$

Therefore:

$$.23 = .75X + .708X^2 + .625X + .708X^2$$

Therefore:

$$X = .108" \quad \text{or}$$

$$H = .165".$$

If T = Thickness of the valve, then

$$\begin{aligned} T &= 1/16 \tan 45^\circ \\ &= 1/16" \end{aligned}$$

Unbalanced Pressure. (P)

Assume city water pressure of 20 lbs.

1. With city pressure on inside of valve.

$$\begin{aligned} P &= .785 \times .75^2 \times 20 - (5/8)^2 \times .785 \times 20 \\ &= 2.69 \text{ lbs.} \end{aligned}$$

2. With city water pressure on outside.

$$\begin{aligned} P &= .785 \times 20 \times (7/8^2 - .5^2) \\ &= 8.10 \text{ lbs.} \end{aligned}$$

This difference in pressure is of course caused by the difference in area of the two valves, made necessary for assembly purposes.

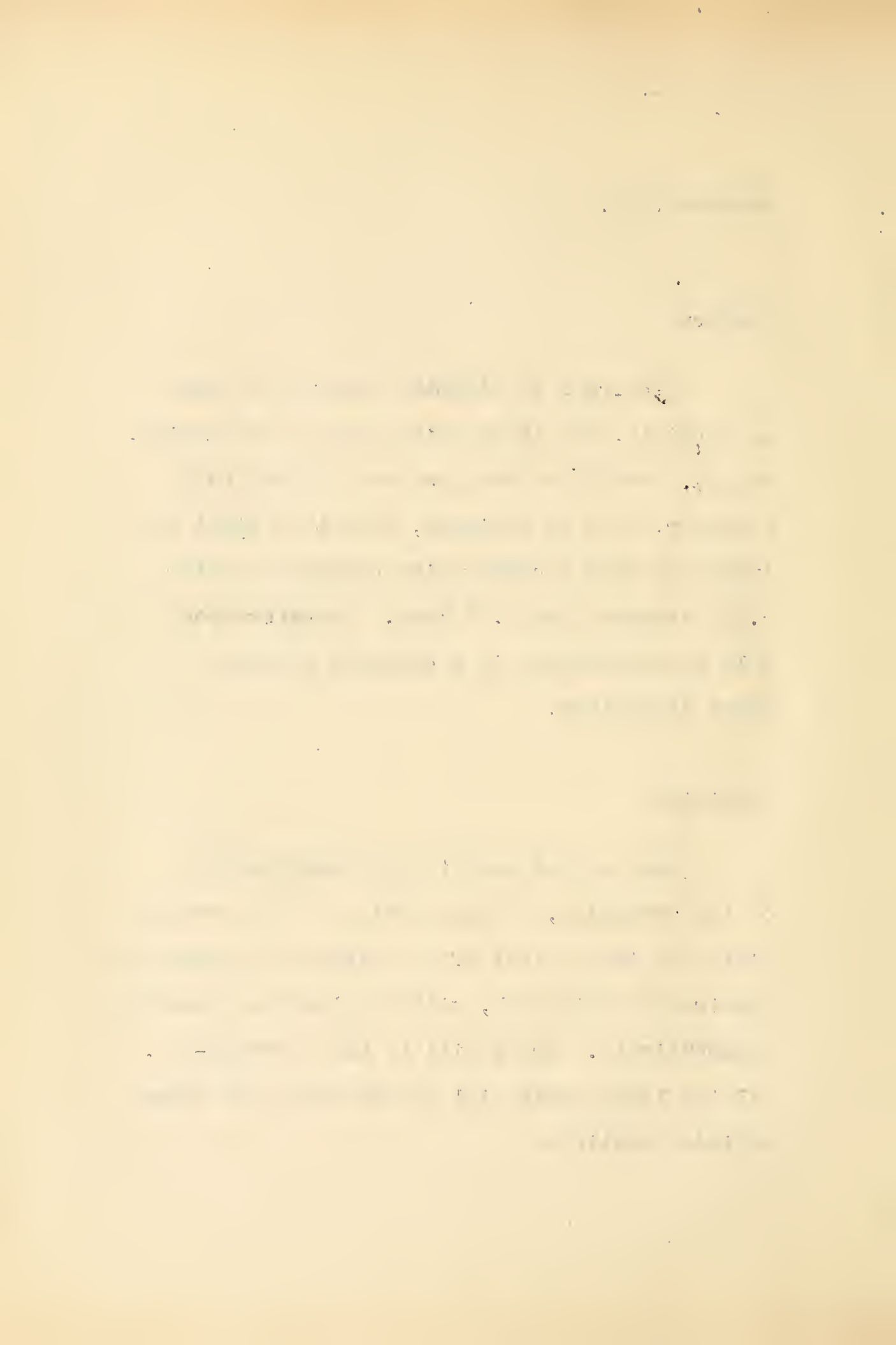
Construction.

Pattern.

In order to minimize the work as much as possible, the three main parts of the device, namely, the valve body, cap and sylphon bulb retainer, were so designed, that they might be turned up from a common size cylinder casting 3.25" diameter and 2.5" long. Therefore the only pattern needed is a cylinder of the above dimensions.

Machining.

Most of the work in the construction of the mechanism, is the machining of the various parts, so that a list of the different operations required in this work, will be given and numbered consecutively. Brass will be used through-out. All the large parts will be made from the brass cylinder castings.



(1) Machining of the Valve Body.

1. Place the cylinder in a chuck and face off both ends to a length of $2 \frac{5}{16}$ " and then turn to a diameter of $3 \frac{1}{8}$ ".
2. Drill a $\frac{19}{64}$ " hole through - out.
3. Ream hole of Operation 2 to $\frac{5}{16}$ ".
4. Bore $\frac{5}{8}$ " hole to a depth of $1 \frac{5}{8}$ " from working face, with $\frac{5}{16}$ " hole as center.
5. Bore a $\frac{7}{8}$ " hole to a depth of $1 \frac{1}{8}$ " from working face, with hole of #4 as center.
6. Turn hole of #5 to a depth of $\frac{9}{16}$ " and to a diameter of 1.659".
7. Thread hole #6, for depth of $\frac{3}{8}$ " with U.S. Standard Thread, 16 threads per inch. This thread and pitch to be used through - out.
8. Place boring tool in work and at a depth of $1 \frac{3}{16}$ " true up a chamber 1" diameter and $\frac{9}{16}$ " long. This forms the inside chamber between the two valves.

9. Extend tool and turn chamber beneath lower valve to $1 \frac{5}{8}$ " diameter making bottom part of said chamber $1 \frac{5}{8}$ " from working face. The chamber should be made the same width as the special tool # 1 which is used for this operation. (See sketch on special tools.)
10. Turn upper seat to 45° with working face and 1" as the maximum diameter.
11. Turn lower seat to 45° with working face and $\frac{7}{8}$ " as the maximum diameter.
12. Turn outside of cylinder to shape and size as shown in drawing.
13. Remove work from chuck and from the working face, drill $\frac{3}{16}$ " holes as close as possible as shown in working drawing, to depth of $1 \frac{1}{16}$ " from face of hole of # 6.
14. With the use of special tool # 2 break down the walls between the holes of # 13 as shown in drawing.
15. Drill and tap for a $\frac{3}{8}$ " pipe, two holes at a height of $1 \frac{5}{16}$ " and $1 \frac{1}{8}$ " from the bottom face respectively and at a depth of $\frac{1}{2}$ "

directly opposite one another and midway between the extreme holes of # 13.

16. In hole # 15, that is $1 \frac{5}{16}$ " from bottom face, drill $1 \frac{1}{2}$ " hole thru the wall into the valve chamber.

17. ReChuck on the other end and cut in bottom face with $\frac{5}{8}$ " drill, a hole $1 \frac{1}{8}$ " deep, in center to form recess of hole #3.

18. Turn outside face of cylinder as shown in drawing , which completes the valve body.

19. Remove from chuck and drill six $\frac{5}{16}$ " holes equally spaced at a distance of $1 \frac{3}{8}$ " from the center, in the bottom face.

Special Tools. (Used in machining valve body)

Special Tool #1.

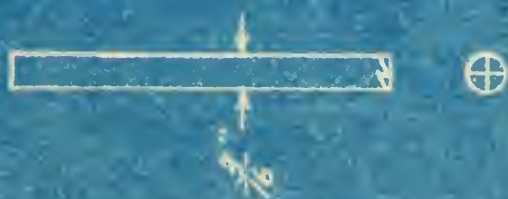
Ordinary boring tool but forged according to size and shape as shown in sketch.

SPECIAL TOOLS.

NO. 1.



NO. 2.



Special Tool # 2.

This tool is made from $3/16$ " drill stock and four cutting edges filled on the end as shown. The shank is given a small clearance and the drill tempered and hardened.

(2) Valve.

1. From a piece of rolled brass, face to a length of $3 \frac{1}{16}$ ".
2. Turn to 1" diameter.
3. On the end turn to $5/16$ " diameter plus or minus .002" for a length of $1 \frac{1}{16}$ ".
4. Turn a groove $5/16$ " diameter and $1 \frac{7}{32}$ " from the end of operation #3 and $5/8$ " wide.
5. Turn the shoulder that is left to $3/4$ " diameter.
6. Turn down the other end of the valve to $19/64$ " diameter plus or minus .002" for a length of $1 \frac{1}{8}$ ".

7. Turn valve seat to 45° with short end, facing # 6.

8. On extreme end of $19/64$ " diameter turn to $1/8$ " diameter and $1/8$ " long.

(3) Joining Screw.

1. Chuck a brass casting in lathe and turn to 2" diameter and $5/8$ " long.

2. Bore a $9/32$ " hole thru the center.

3. Ream hole of # 2 to $19/64$ ".

4. Turn casting to $1\ 11/16$ " diameter for a length of $5/16$ ".

5. On #4 chase threads 16 per inch.

6. On middle of casting turn recess $1/8$ " wide and $1\ 9/16$ " diameter.

7. Turn other end of casting to 2" diameter.

8. Turn 16 threads per inch on # 7.

9. Re Chuck and face off ends.

(4) Sylphon Top # 1.

1. From a piece of stock, turn a disk to form a snug fit inside the top of the sylphon bulb.
2. Face off both ends so that it is $3/16$ " thick.

(5) Sylphon Top # 2.

1. From a similar piece of stock as in (4) turn a disk to fit inside the other end of the sylphon bulb.
2. Turn to $5/16$ " thick.
3. Reduce diameter of disk to $1\ 1/2$ " for a length of $1/4$ ".
4. On # 3 chase 16 threads to inch.
5. Drill and tap in the center of the disk, a hole to fit $1/4$ " standard bolt.

(6) Sylphon Retainer.

1. Chuck and face off another cylinder casting.

2. Turn to a diameter of $3 \frac{1}{8}$ ".
3. Drill thru center a 1" hole.
4. Bore hole # 3 to $1 \frac{1}{2}$ ".
5. Bore hole of # 4 to $2 \frac{1}{16}$ " for a depth of $2 \frac{5}{32}$ " so as to admit the syphon bulb and make a loose fit.
6. Reverse and rechuck and face to length of $2 \frac{5}{16}$ ".
7. Thread hole # 4 with 16 threads per inch.
8. Remove from chuck and carefully drill twelve one inch holes in the side of the retainer, staggering them.
9. Drill and tap six holes for $\frac{1}{4}$ " standard bolts on the $3 \frac{1}{8}$ " face at a distance of $1 \frac{3}{8}$ " from the center, equally spaced.

(7) Cap.

1. Face and turn another casting to $3 \frac{1}{8}$ " diameter.
2. Drill thru center a $\frac{1}{4}$ " hole.

3. Drill in center a 1" hole, $2 \frac{1}{8}$ " deep.
4. Bore hole #3 to 2" diameter for the full depth.
5. Turn hole # 4 to $2 \frac{1}{4}$ " except for a distance of $\frac{1}{2}$ " from the face.
6. Turn on inside shoulder 16 threads per inch.
7. Knurl shoulder on the outside.
8. Reverse, rechuck and turn outside to $2 \frac{3}{4}$ " diameter for a distance of $1 \frac{3}{4}$ ".
9. Face end so that length is $2 \frac{9}{16}$ ".
10. Remove from chuck and tap hole #2 with $\frac{3}{8}$ " standard tap.
11. Drill two holes $\frac{3}{8}$ " diameter directly opposite each other, at a depth of $\frac{3}{8}$ " on knurled face.
12. Force in holes # 11, two $\frac{3}{8}$ " brass rods each $1 \frac{1}{4}$ " long.
13. Round the ends of rods # 12.

(8) Spring Retainers. (5 wanted)

1. Turn cylinder $\frac{7}{8}$ " long and $1 \frac{3}{8}$ " diameter.

2. Drill thru center a $1/8$ " hole.
3. Bore hole $1\ 3/16$ " diameter and $5/16$ " deep forming cup.

(9) Spring Regulating Screw.

1. From 1" stock cut a piece $1\ 5/8$ " long.
2. Turn for a length $7/8$ " to a diameter of $3/8$ ".
3. Thread part of # 2 with $3/8$ " standard die.
4. Put in milling machine and cut a hexagonal head on the screw.
5. Drill a $1/8$ " hole in the head and at right angles to it.
6. Force in hole # 5 an $1/8$ " brass rod $1\ 3/4$ " long so that it extends equally on both sides.
7. Round the ends of rod #6.

Bench Work.

Sylphon.

With a hot soldering iron the joining

parts of the sylphon bulb, are heated and well tinned as these parts must be so soldered together , that under pressure they will not leak. In this manner the two sylphon tops are sweated securely in the sylphon bulb.

Valve.

With a fine gringing compound on the valve, it is inserted in the valve body and ground in until Prussian Blue shows a fairly good seat. This seat will be found to be quite leaky under water pressure, therefore the valve is placed in the chick of a high speed lathe and the valve body pressed on the seat by means of the tailstock. By the use of plenty oil and no compound, the valve is burnished in until the operation gives a perfect seat.

Gaskets.

Two rubber gaskets are cut out, namely, one for each face of the valve body.

Assembly.

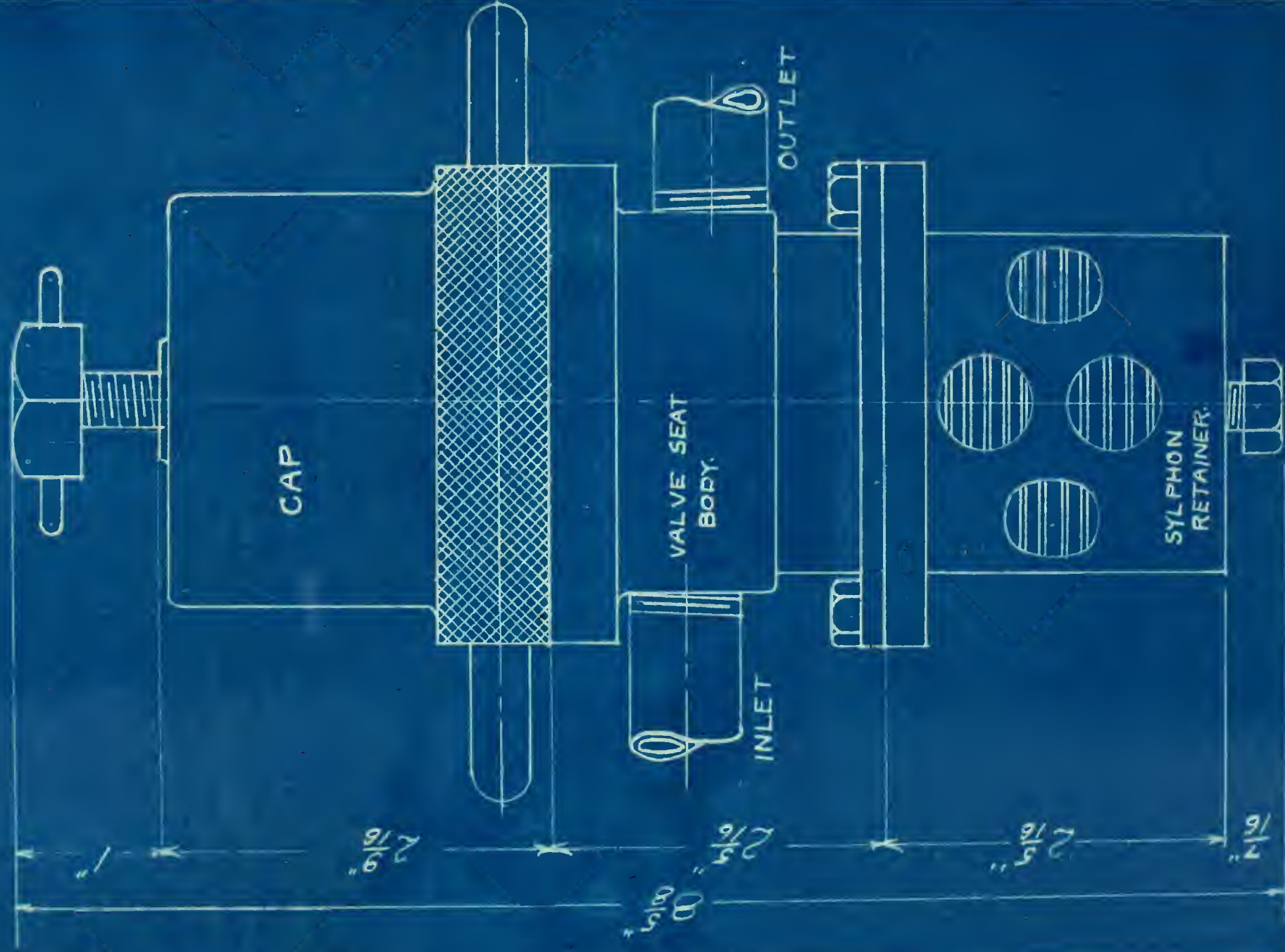
The valve is placed in the valve body and the sylphon bulb screwed into its container, then the two are bolted together with one of the gaskets between them. The other gasket is then placed on top of the valve body and the joining screw placed in position. One of the spring retainers is then put on top of the valve stem and the other on the end of the regulating screw that passes thru the top of the cap.

A spring is then placed in the retainer, (See test data for strength of spring needed) and the cap screwed down. The valve is then turned upside down and the sylphon bulb is then partly filled with the desired liquid found by test and the hole then plugged up with a bolt.

The bulb is only partly filled, to compensate for the change in temperature. If the bulb were filled on a day when the temperature was low, the liquid would have contracted

VERTICAL VIEW OF
THERMOSTATIC

VERTICAL VIEW OF THERMOSTATIC JACKET WATER CONTROL.



and the bulb would not touch the valve stem ; this would cause the valve to operate at a wrong temperature. If the bulb had been filled on a hot day, the liquid would have already expanded and so give improper regulation. The bulb is partly filled so as to give the proper action at 150°F.

The valve is now complete and ready to be placed on the engine. The piping is clearly shown in the drawing of General Installation for a eight cylinder Buda Engine.

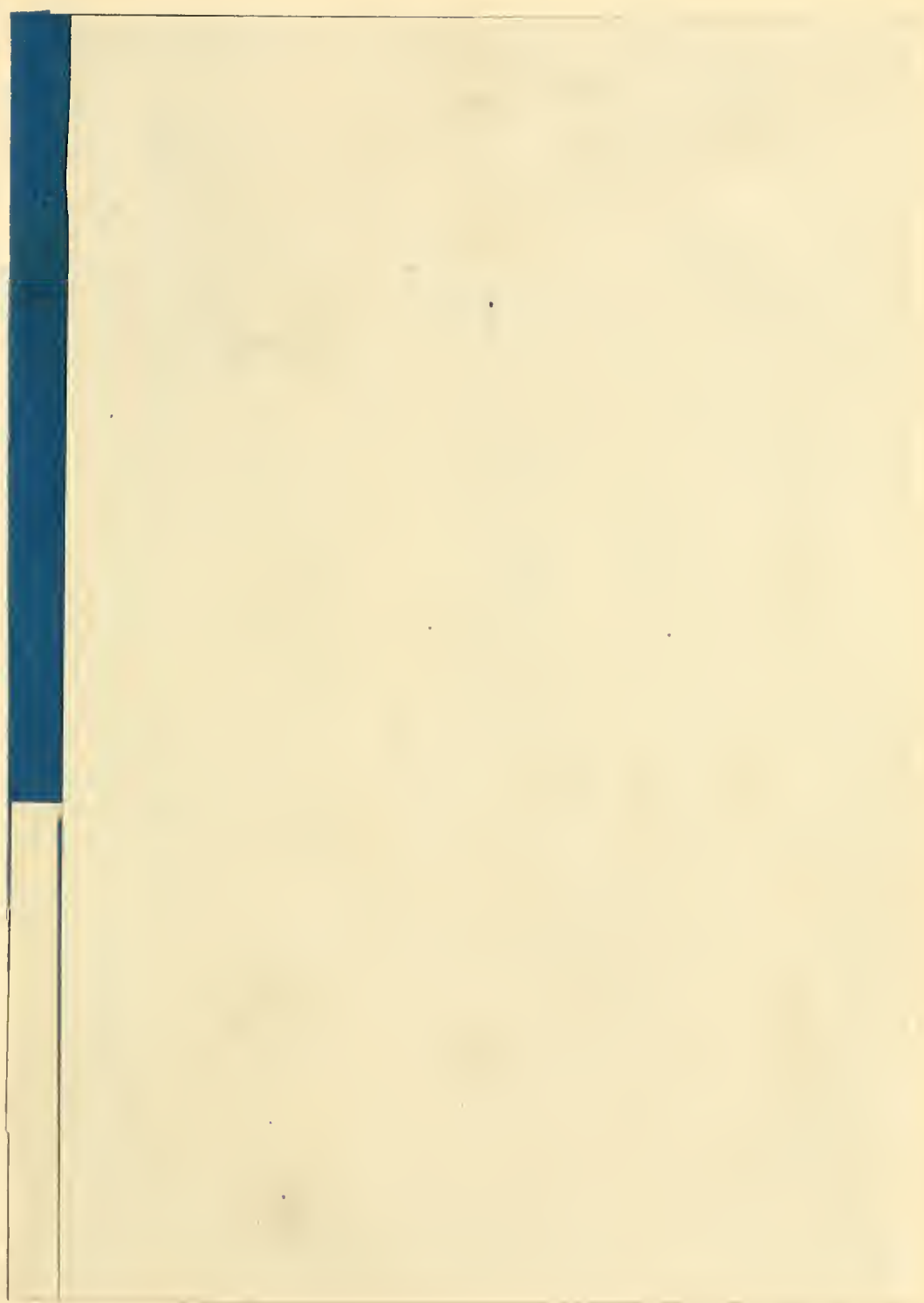
Testing.

The testing divides itself into two parts:

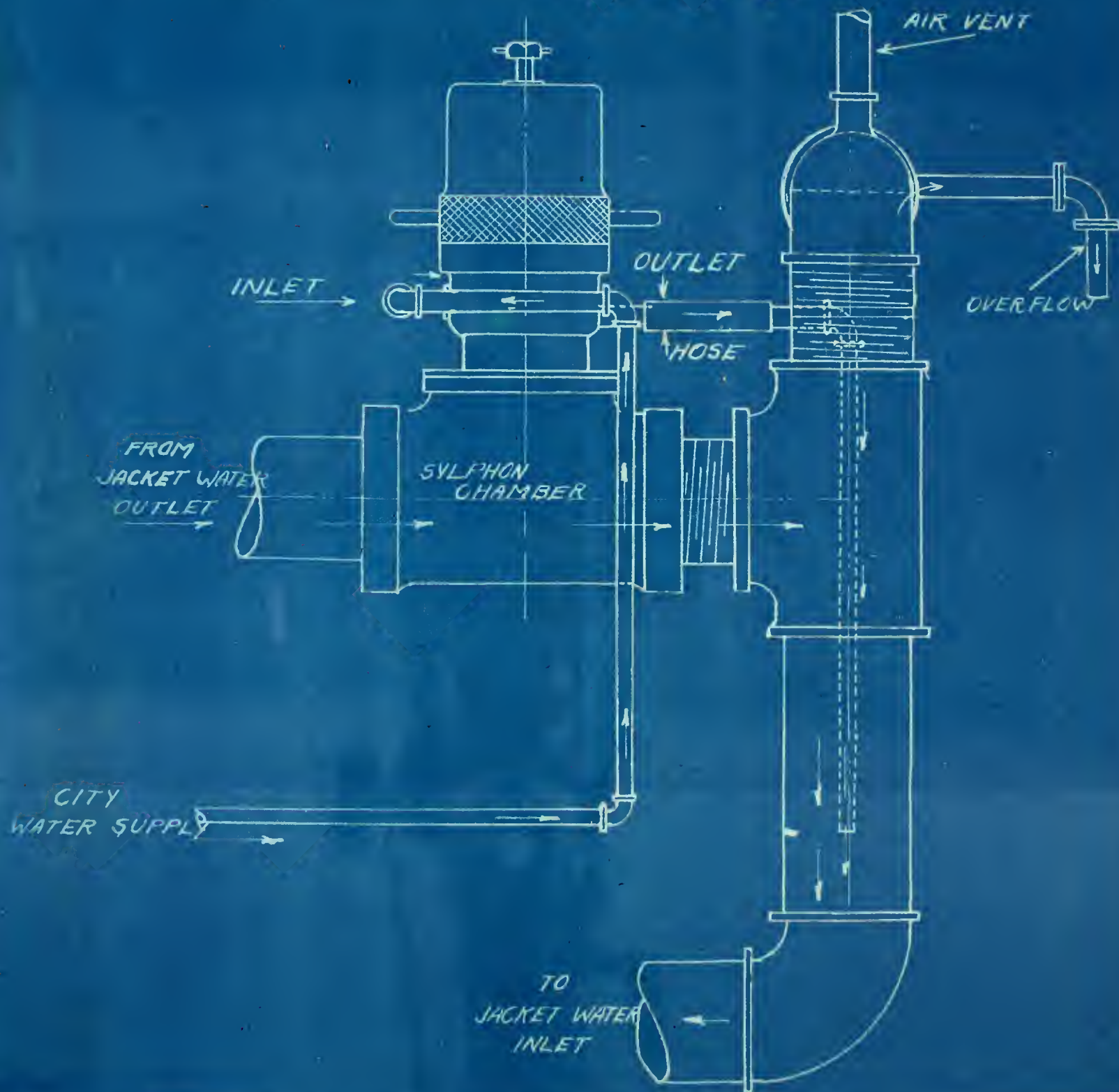
1. Finding the proper liquid to be used in the bulb.
2. Testing of the valve under actual conditions.

Part 1.

The investigation as to what kind of liquid to use in the bulb for the best results, is one



GENERAL INSTALATION.





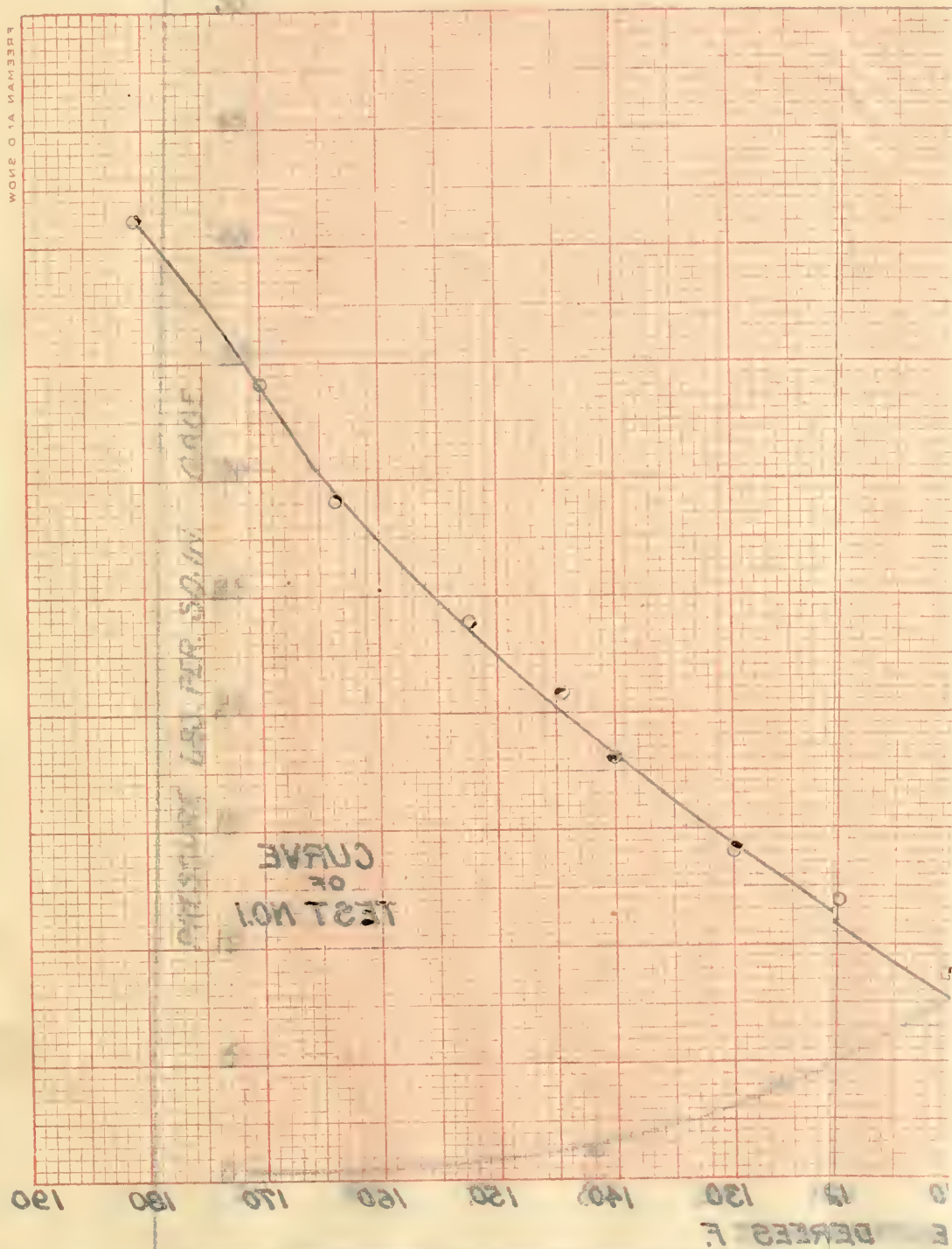
upon which weeks of research work could be easily spent. In our case we know that the liquid must be volatile and so we chose the one at hand, namely, gasoline ether. Fortunately it served our purpose very nicely as can be seen from the data obtained.

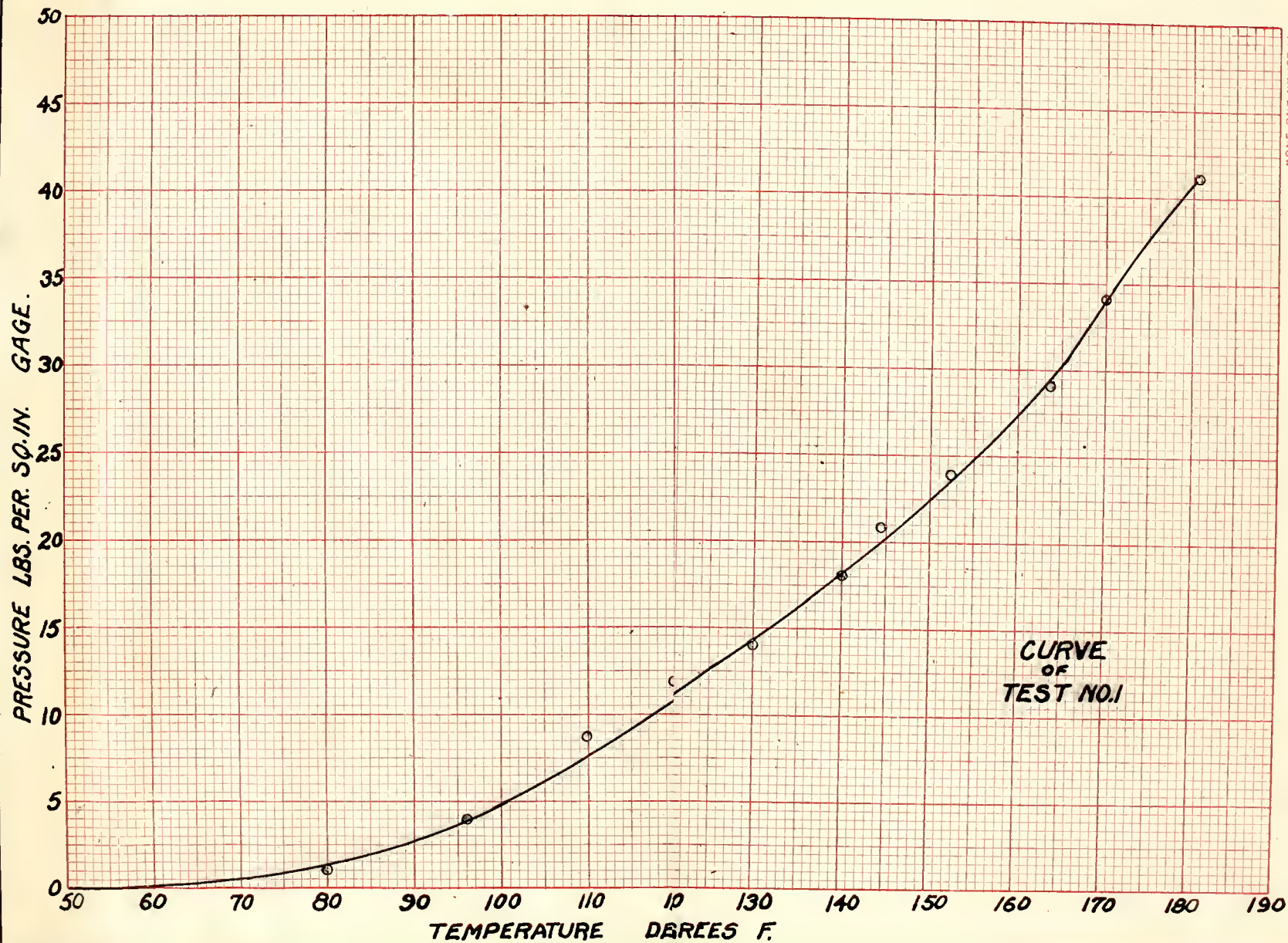
The expansion bulb used in the early part of the experimenting, was simply a small cup with fins turned on it, this served for better conduction of heat. It was piped up to the sylvphon bulb with a flexible copper tube.

The lever and weight used with our apparatus is shown in the drawing of Layout of Apparatus During Run of Tests, was easily constructed and served our purpose satisfactorily, so it was erected instead of the spring.

Test # 1.

A bulb containing hight test gasoline of 86° B. with the remote control connection, was placed in a water bath where the temperature could be controlled.





This testing was run for determining the relation between the temperature and pressure. Removing the lower part of the valve which contained the sylphon, and clamping it so that it could not expand, a pressure gage was inserted in the line so that the pressures developed by applying heat could be read and noted.

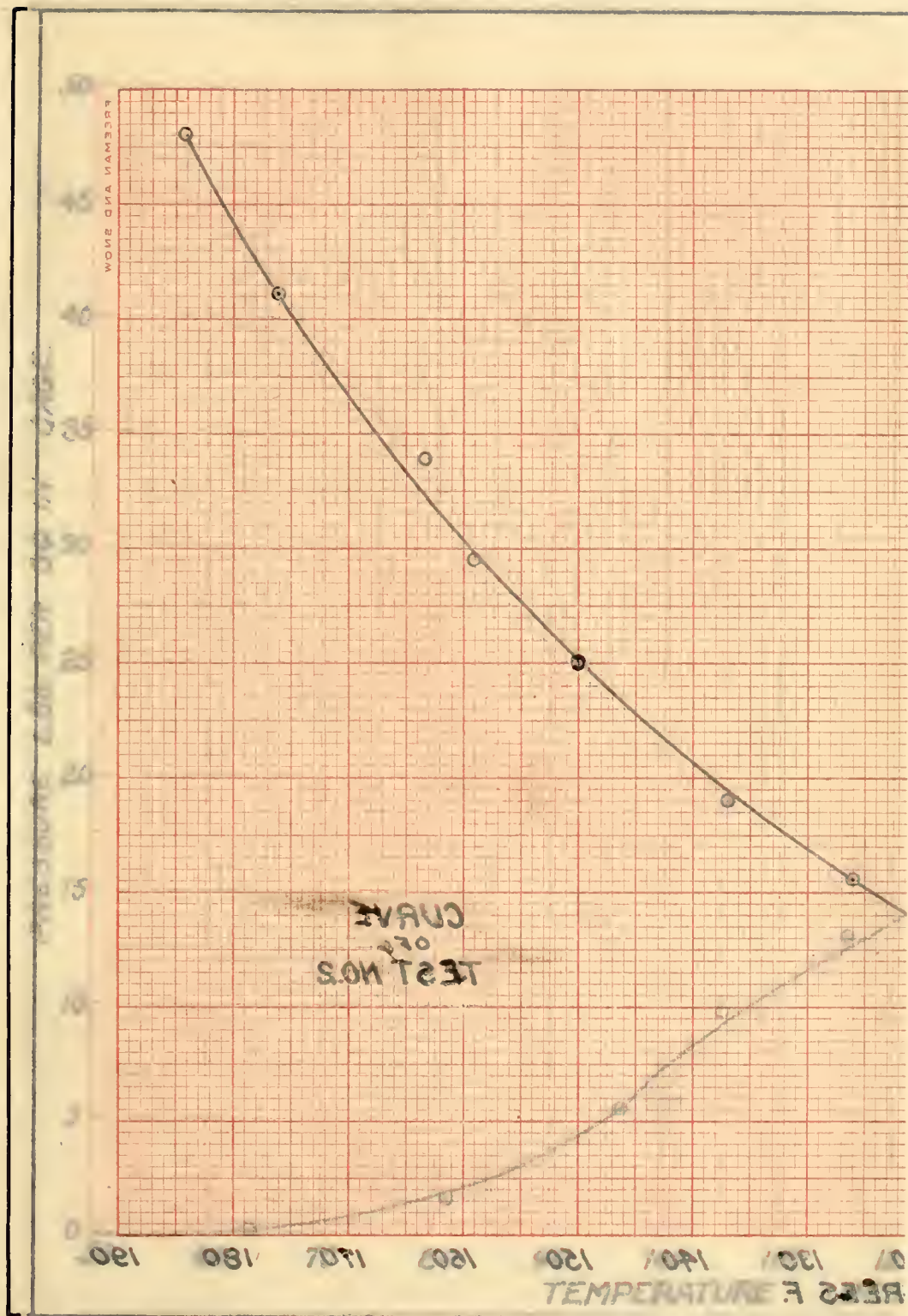
Data of Test #1.

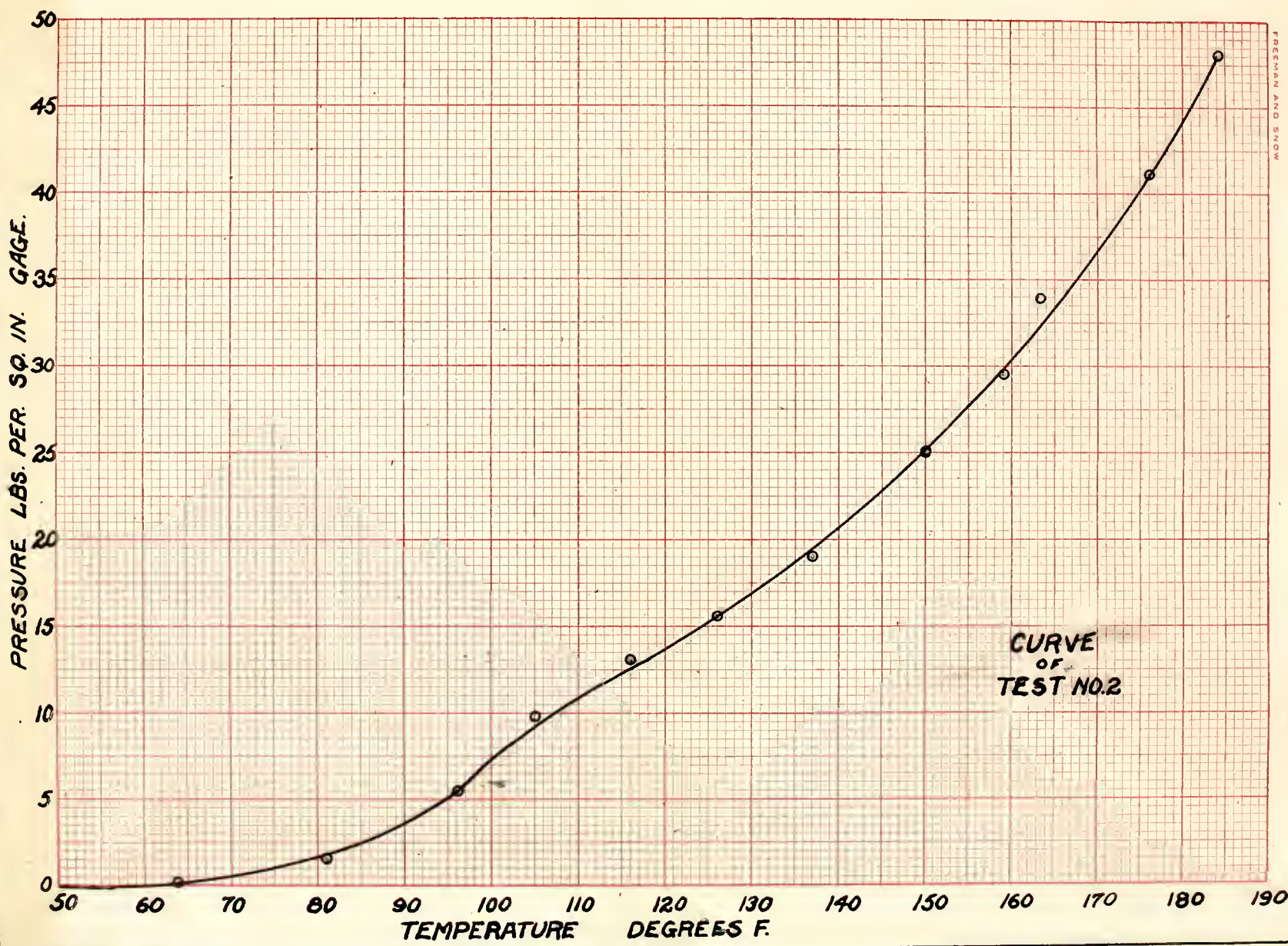
Temperature °F.	Pressure lbs. Gage
37	0
80	1
96	4
110	9
120	12
130	14
140	18
152	21
164	24
166	29
170	34
181	41

From the data and curves we saw that the pressure obtained was not quite as high as desired, due to the fact that only the liquid in the expansion bulb was vaporized by the heat of the water to be controlled. The liquid in the expansion bulb was a small part of the entire liquid, so we decided to dispense with remote control, and immerse the entire sylphon bulb in the water. The figures show that with the small expansion bulb of only three cc., in the bath, we would be bound to get pressures somewhat less than if we immersed the entire sylphon bulb.

Test # 2.

The conditions were improved according to the conclusions reached in test # 1. This run without remote control, shows that we did get higher pressures and that the curve around our working temperature of 150°F . is much steeper.





This is just what is wanted. A slight rise in temperature results in an increased pressure, opening the valve. With the resulting close regulation, we decided to use this method of entire immersion of the sylphon bulb, and the use of gasoline ether of 86° B.

Data of Test # 2.

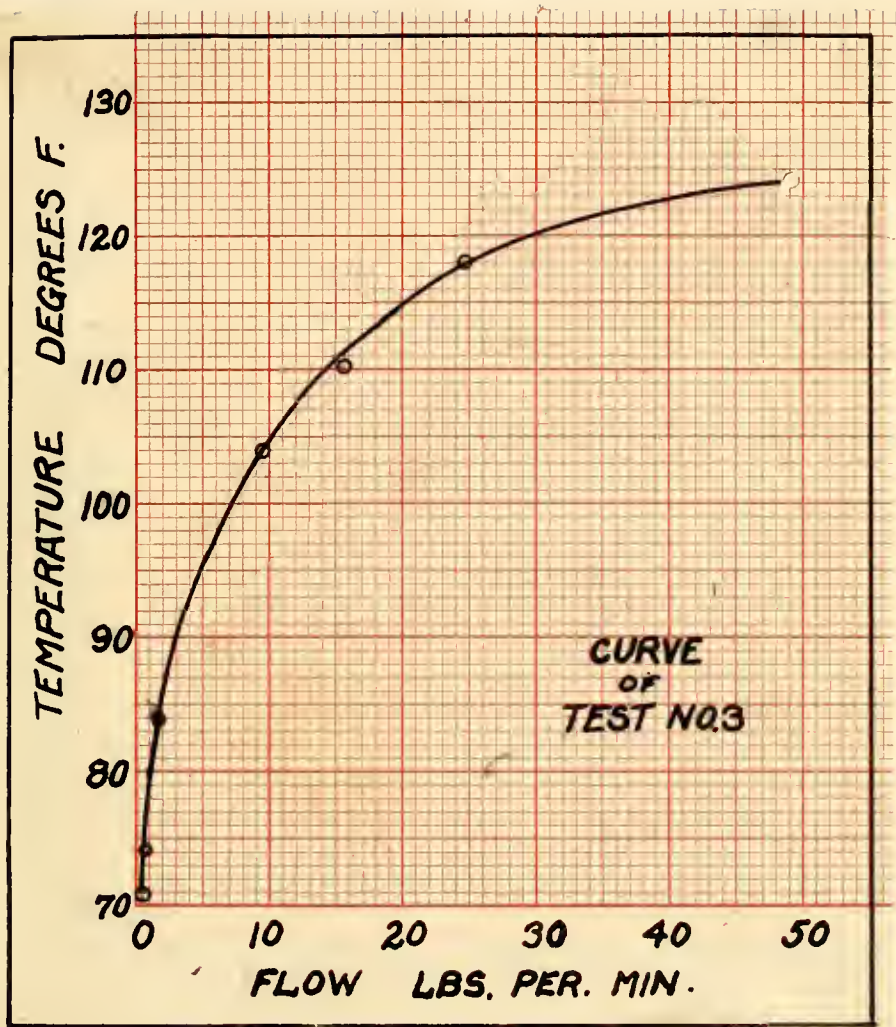
Temperature in ° F.	Pressure lbs, Gage.
44	1 1/2
64	0
81	1 1/2
96	5 1/2
105	10
116	13
126	15 1/2
137	19
145	23 1/2
150	25
159	29 1/2
163	34
170	38 1/2
176	41
184	48

Test #. 3.

This test was one more or less under actual conditions. The object was to determine the flow with a variation in temperature and pressure. Weights were placed upon the lever, which was used for regulation, as previously stated, until the valve opened at 150° F. It was found impossible to eliminate all leakage by the valve at normal temperatures; this was due to the impossibility of getting a perfect seat for the valve. Being very small, it did not effect the temperature of the jacket water in any way.

The pressure placed upon the valve was found to be 116# by experiment as previously told. This pressure was evidently too great and investigation showed that the valve stem was too long, which caused the sylphon bulb to be compressed too far before the valve would open, and seat. This is shown by the following data.



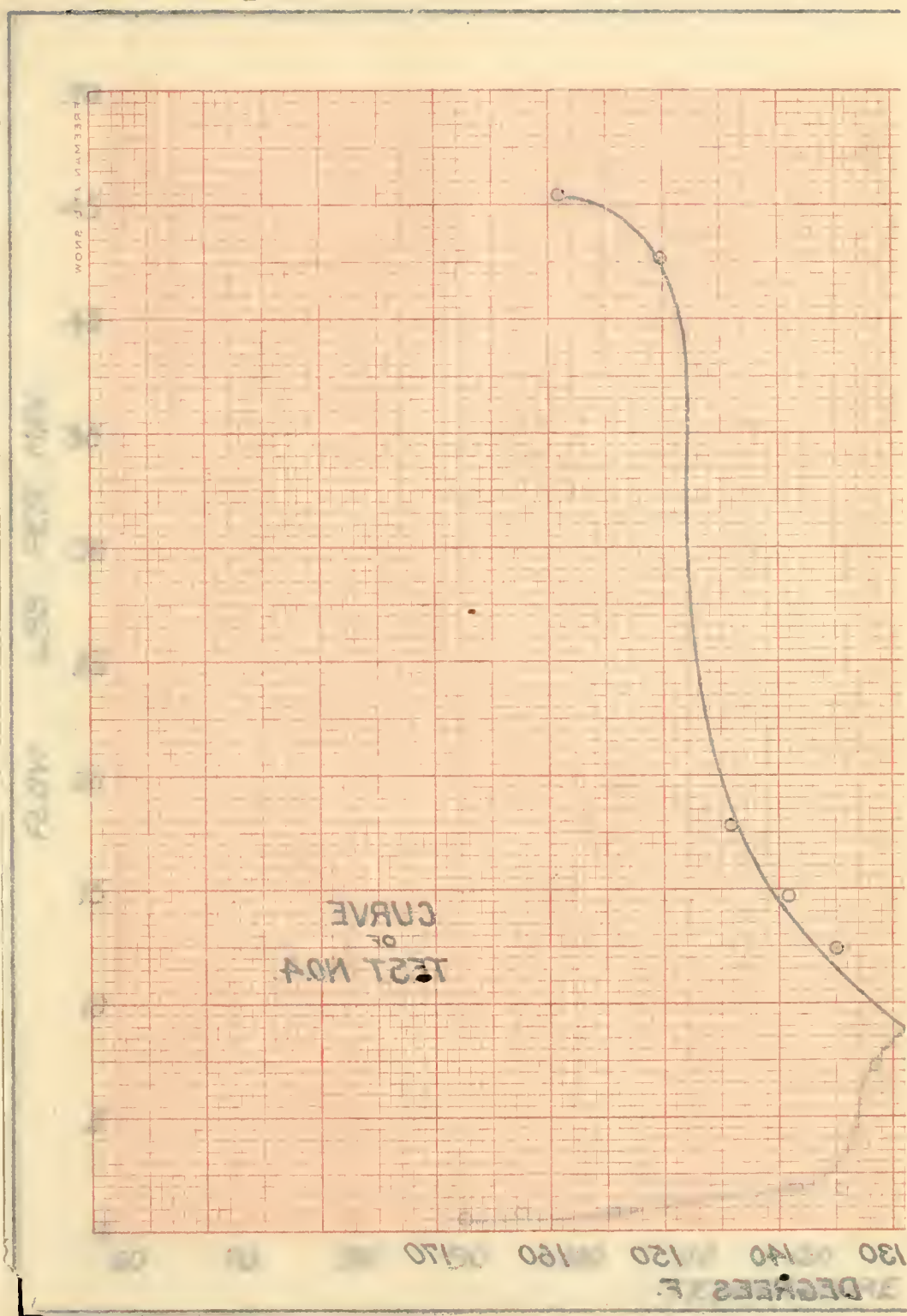


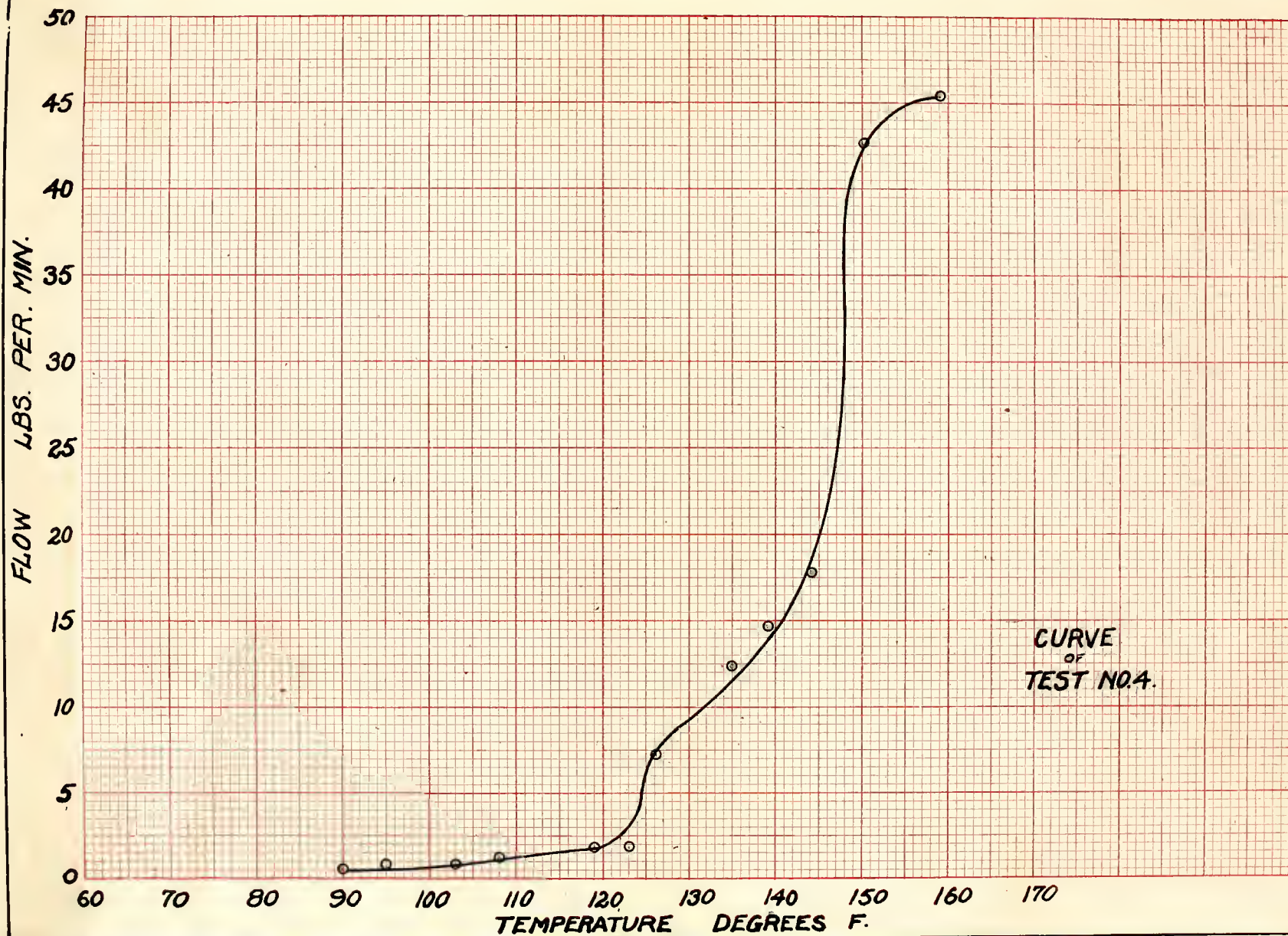
Dat of Test #3.

Temperature in ^o F.	Flow in lbs./mn.
74	.1
84	.85
104	9.5
110	15.7
118	24.8
124	49.4

Test # 4.

From the preceding test, the results were very poor. With a pressure of 116# the valve started to open at 110^oF. Our requirements being, the valve should open around 150^oF. so by shortening the valve stem the difficulty was removed. The data of this test which was run with the suggested improvements, shows that with a pressure of 63 # on the valve, the results were in accordance with what was wanted.





Dat of Test # 4.

Temperature in °F.	Flow in lbs. / mm.
68	.5
79.6	.35
90	.4
95	.85
103	.5
108	1.2
119	1.9
123	1.9
126	3.2
129 1/2	5.2
135	12.4
139	14.7
144	17.9
150	42.6
150	45.4

These results show that up to 120° the valve was shut, and only such flow as the imperfection of the valve, allowed to pass.

The most important point to note, is that at our desired temperature of 150° a sudden opening of the valve took place and that below 144° it was practically closed. With these results which were those desired, it was possible to go ahead on the actual installation and final testing.

Test # 5.

With the valve installed on the engine, as shown in the drawing ' General Installation ' and the small photographs, we started our testing with the same conditions as those of test # 4 namely 63 # pressure on the valve. A thermometer was placed just above the water jacket so that the effect of the valve would be measured after the water had passed thru the valve and jacket. Starting the engine when cold and with a light load, we recorded the following facts:

Data of Test # 5.

Temperature in °F.	Flow.
55	No Flow
85	"
97 .	Slight Flow
110	"
130	Slight Increase
144	"
150	About double
151	that
149	at
155	130°F.
154	

(Note: The flow was estimated by observing
the amount coming out of the overflow pipe)

For the remainder of the run, the temperature
never varied more than 2° either side of 154°, and
most of the time stayed very close to 154°, which
showed that the valve was hunting continuously

Other tests followed, reducing and increasing the load on the valve by means of the addition or subtraction of weights on the lever, which caused the temperature to rise and fall respectively. As for instance:

Temperature	Pressure
139-142	46
150- <u>154</u>	51

With these results we concluded that our valve had come up to expectations, even tho we believe that improvements can be made. Various difficulties both in construction and testing had to be remedied and with these in mind, new designs were drawn up.

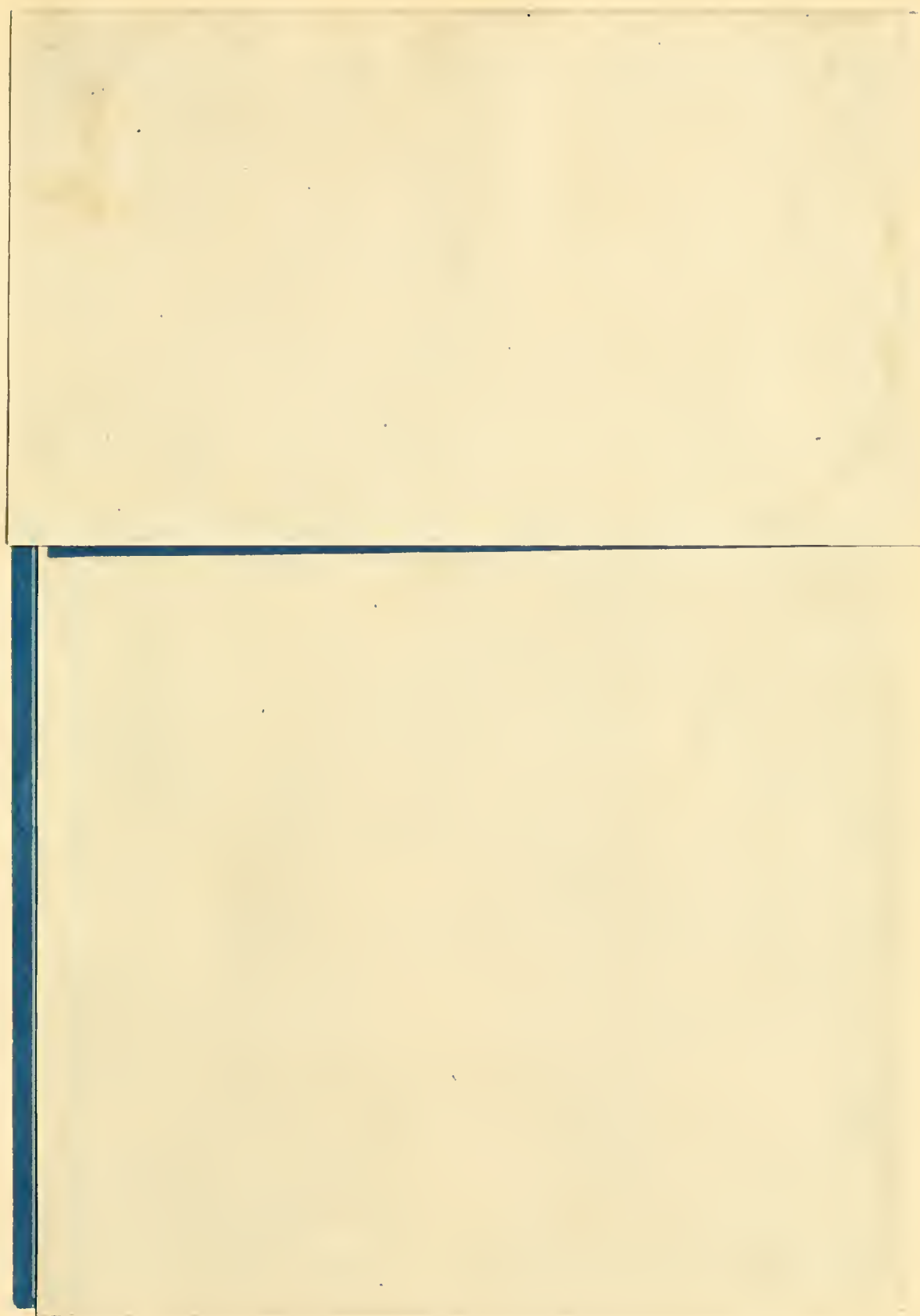
Discussion and Redesign.

Upon consideration it was thought advisable to make not only the valve but also the tee, into which the sylphon bulb retainer fits, a unit;

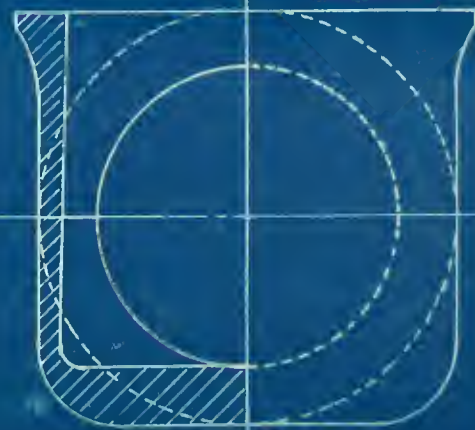
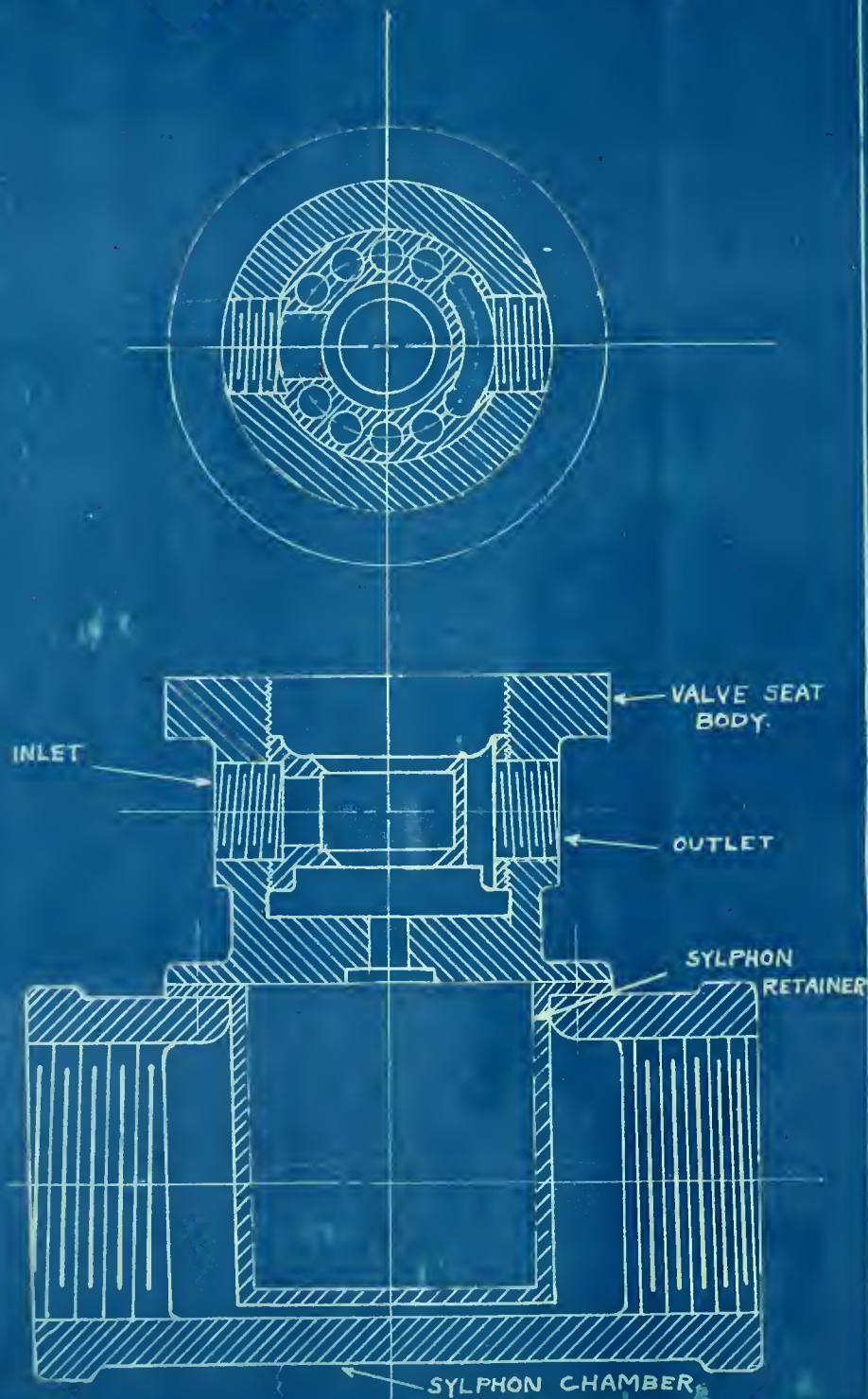








PROPOSED DESIGN #1



This is shown in drawing ' Proposed Design # 1.' By this method the tee takes the place of the syphon bulb chamber and being threaded for a standard pipe, it can be readily inserted in the cooling system of any engine.

The next consideration was one of considerable importance, namely the valve. Calculations show that on a single valve , as shown in ' Proposed Design # 2 ' show the pressure to be fairly small.

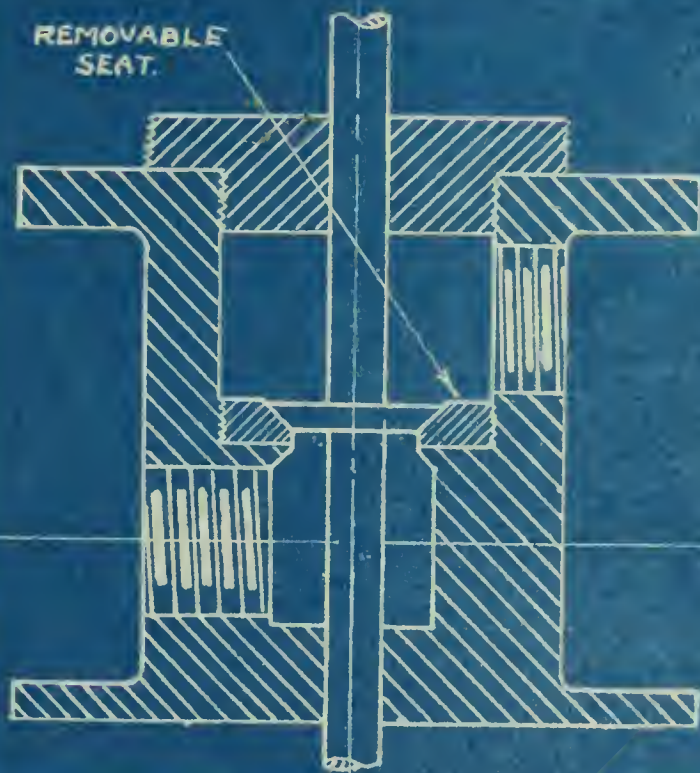
On a 7/8" valve it will be

$$7/8 \times 7/8 \times .785 \times 20 = 12 \#$$

Although the un-balanced pressure is large as compared with that of the balanced valve, it is in reality small.

No doubt a valve of this type would not be as sensitive as the balanced one, but the other advantages must be considered. With a balanced valve it is very difficult to obtain a perfect seat, as both the upper and the lower seat must be ground in together.

PROPOSED DESIGN
UNBALANCED. *2.



If one part of the valve is a little softer than the rest, it will wear away faster than the other part of the valve, this will naturally make a leaky valve. Inherently it is defective as the least difference in one seat from the other will result in the other not seating properly. With the single valve, the preceding difficulty is overcome as one valve can be ground in easily and then there is nothing to prevent it from seating.

If the valve seats are made in the form of a cage, the whole valve can be removed and ground in separately. By cutting threads on the outside of the cage and corresponding ones in the valve body, a very convenient form of valve will be the result. Shown in 'Proposed Design # 1 and # 2'. With this construction and in addition the single valve, we may overcome the greatest part of the difficulties encountered in the type ~~that was~~ constructed.

In this from the valve can be ground in after wear or some mishap, without the removal of the entire mechanism as was necessary in the old type. In case the valve seat becomes warped scored, or in any other way injured, so that it could not be of further use, it would be a simple matter to turn up a new cage, as compared with the replacing on an entire new valve body of the old design.

The possibility for closer regulation by this method seems quite doubtful. In the first place the thermostat depends upon the temperature around it and in order to have the entire system at a constant temperature, it would be necessary to insert a number of valves and have perfect mixing of the cooling water. The best that can be done under our conditions, is to keep the temperature in one part of the system fairly constant. Perhaps the most desirable place is where we have chosen, namely , just above the jacket water, this provides the engine with protection as it is here where the hottest water collects.

Mechanical controls of the nature of this valve, are bound to require certain pressures above that desired for operation, for we must overcome not only the un-balanced pressure on the valve but also that due to friction. Therefore indications seem to point to some other means of regulation for close temperatures, perhaps some electrical device; but in this work it is needless to discuss or investigate this part of the problem, as there are many other items in gas engine testing that are far less accurate than the maximum 4° variation obtained.

More than likely, the future design will not deal with accuracy or sensitiveness, but rather with ruggedness, simplicity and ease of construction. Proposed Design #2 is of this type. We realize that our device can be improved upon especially if it should be manufactured commercially.

As our initial desire was to control the jacket water under the conditions as discussed in the early part of this paper, and as the

successs for which we have been striving has been attained, to the extent that our time has allowed; we trust that the instrument constructed by us, according to our own design and now in use on one of the engines in the Gas Engine Laboratory of Armour Institute of Technology, will be satisfactory for many years. No doubt some day, a new design and construction will replace ours; an improvement over it's predecessor.

FINIS.

